Art. XV.—*On the Performance of Some Timekeepers.*

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At the International Exhibition held in Melbourne in 1880-1881, there was a fine display of clocks and watches of nearly every kind, as almost every country celebrated for their manufacture was well represented. The principal deficiency was with the clocks; of these the English sent few specimens, and the principal part of the American exhibit was lost by shipwreck. It became part of my duty, as a juror, to examine these, and from my position in the Observatory I had to take part in their testing. The result has been published in the Official Record of the Exhibition. I have been several times asked, however, whether the method of testing adopted, in which the watches were kept in stands, was a proper trial for an article like a watch, which is generally carried in the pocket, and is, therefore, subjected to all the motions of the body; that these motions are anything but slight, even in inactive persons, may be proved by a ride in a vehicle along the St. Kilda Road. My interest having been excited, and having unusual facilities for the purpose at the Observatory, I determined to test some watches in what may be called a natural way—that is, whilst being worn during the day and put under the pillow or hung up at night. For this purpose I purchased one or two of the fine watches from the Exhibition; these, together with one in my possession before, and some confided to me by friends for regulating, formed the subjects of my trials, the results of which, together with a few others from different sources, form the subject of my paper to night.

Nearly all the timekeepers of the present day may be divided into two classes—clocks and watches; the former, I shall call those which have their motions regulated by a pendulum, controlled by gravity; and the latter, those whose motions are regulated by a spring governed by its elasticity. Many of these latter are commonly called clocks, such as carriage clocks, lever clocks, &c.; they are, however, really watches, and will go in any position, whereas a clock requires to be kept at a certain definite angle with the horizon, and although marine chronometers are intended to be kept in one position, yet they will go in any, and they are only a superior class of watches. In using the term watch, however, without any qualification, we usually mean one of from about an inch to two inches diameter, so that it can be conveniently worn in the waistcoat pocket.

In ordinary talk, watches are usually named from their outward cases, as a gold watch, a silver watch, an open face, or a hunter; it is needless to observe that this classification is totally useless as a guide to the quality of the mechanism. Occasionally they are called after their nationality, English, American, or Swiss watches; in this case we can generally form an idea as to their internal arrangements, though the lines of demarcation are now much more faint than formerly. The typical English watch has a full-plate movement, covered with a cap, the whole of which opens out from the case on a hinge, and the hands are set from the front; its most distinguishing feature, however, is the fusee with its chain to equalise the motion of the mainspring, which is retained in watches of even the lowest class. English watches were formerly noted for their durability and time-keeping qualities. In this latter quality, however, they are now greatly excelled by the American (and when I say American, I mean Waltham, for I have had little experience of their other makes) and by the better class, yet moderately priced, Swiss watches. Still, the highest class English watch, which is also a very expensive article, is a perfect triumph of skilled work, and is unrivalled as a timekeeper. At the same time, the other extreme is reached by the low-priced English productions, which are a disgrace to the science of horology. The Waltham watch has usually a three-quarter plate, a going barrel without stopwork, so that the mainspring can act throughout its whole length; the case opens, and the hands are set at the back, and it has a real compensation balance in lower grades than is usually found in English and Swiss watches. No other escapement is used, I believe, than the lever with open jewels for pallets. The pivots are larger than in most other watches. It is, on the whole, a most substantial piece of work, and is a first-class timekeeper. In this respect, indeed, I think the lower grades of Walthams are unapproachable. I have found them keeping better time than English watches costing five times the money. Their moderate price is due mainly to the absence of much of that manual labour which is used in other countries to finish the parts after they have been formed by the machines ; so, to a watchmaker's eye, they do not present that finished appearance he so dearly loves ; but, as Sir Edmund Beckett says, "so long as smooth work which everybody can see is easier than accurate work which few people can judge of, watches, like other things, will be got up for show." Old Mr. Dent used to say—"We must work for the fools." First-class Walthams, however, have no lack of finish—indeed, they gained the first prize at our Exhibition for their artistic qualities.

Swiss watches are characterised by great delicacy of construction, and by delicacy I do not necessarily mean weakness. They have going barrels with stopwork, so that only a selected portion of the mainspring is brought into action. The cases open, and the hands are set at the back; and the top pivots, instead of turning in holes made in a full or three-quarter plate, work in cocks and bridge pieces, so that most of the wheels may be removed without disturbing the others. The best Swiss watches, though somewhat expensive, are excellent timekeepers, and in the making of small, complicated, and low-priced watches the Swiss are unsurpassed. They also exhibit great variety in their escapements. A few years ago I should have said that the cylinder, or horizontal escapement, was a special feature in Swiss watches. It is now, however, getting supplanted by the lever.

French and German watches were also shown at our Exhibition. They are constructed somewhat like the Swiss, but I think that they are scarcely brought to Australia yet in commercial quantities. The former were not sent to be tested at the Observatory, so that I cannot speak of their performances ; and some of the watches sent out were not exhibited at all, owing to some trouble at the Custom-house. The German watches, as exhibited by the celebrated makers, Lange and Söhne, of Glashütte, near Dresden, proved themselves to be of first-rate excellence and moderate in price.

Instead, however, of a national classification, watches for scientific purposes are generally called after their escapements. The mechanism of a watch, as is well known, consists of a train of wheels impelled by a large coiled spring at one end, and regulated by the reciprocating motion of a very small spiral spring attached to the axis of a wheel with a heavy rim, called the balance, at the other end, together with hands and a dial to indicate the revolutions of some of the wheels. If the short hand of a common watch makes two revolutions while the earth is turning once round, as referred to a fictitious regularly-moving sun in the heavens, which is never very far from the real sun, then the watch is said to be keeping exact time. If, however, the watch be required for astronomical work, and to keep what is called sidereal time, then the short hand should make two revolutions while the earth turns once on its axis, as referred to a fixed star. There is, therefore, no difference in the mechanism of a mean-time and sidereal watch; the latter simply gains 3 mins. 56·55 secs. a day on the former, or one day in a year. In a watch train that part of the mechanism which converts the continuous revolutions of the last, or, as it is called, the scape wheel, into the reciprocating motion of the balance, is called the escapement, and on its construction, as well as that of the regulating spring (which is called the hair or balance spring) and the balance itself, the timing qualities of a watch chiefly depend.

The oldest form of escapement is that known as the verge or vertical escapement. From the time of the invention of watches till about the commencement of the present century, a period of about two hundred years, it was almost the only escapement used. It is now rarely met with, in Australia at least, except in the form of the old, thick, double-cased watch—the well-known "turnip" as it is somewhat irreverently called. I see, however, according to Saunier, that more than 300,000 of watches with verge escapements are annually made in one of the cantons of Switzerland. Very few of these, however, find their way out here. In this escapement the plane of the scape wheel is at right angles to those of the other wheels, so that when the watch is laid flat it stands vertical. Hence the name. This necessitates the watch being of considerable thickness, as well as the use of either bevelled or crown wheels. The principal advantage of the verge escapement seems to be that the impulses are given so directly that the pallets require no oil. It seldom requires cleaning, so that the watch will go with an amount of dirt that would be fatal to the action of most others. Its disadvantages are that the impacts are so severe and so applied as to cause a recoil action of the train. This causes it to wear out rapidly. At the same time it so hampers the free motion of the balance spring that, notwithstanding the presence of the fusee to equalise the action of the motive power, which is absolutely necessary with this escapement, it is a very poor timekeeper. Sully, a celebrated English watchmaker of the last century, found that in the verge watches of his day an increase of one-half in the motive power caused a variation of six hours a day. Captain Cuttle's watch, immortalised by Dickens, had undoubtedly a verge escapement.

The duplex escapement derives its name from the double set of teeth on the scape wheel—a short set to give the impulse to the balance, and a long set to keep the train at rest, except at the moment of escape. It was invented near the end of the seventeenth century. Its inventor is not known with certainty. It was claimed, however, by the celebrated Robert Hooke, the contemporary, and in some degree the competitor, of the great Newton, many of whose discoveries he claimed for himself. He was undoubtedly one of the greatest inventors that ever existed. We owe to him the first investigation of and discovery of the isochronal properties of springs, and their application to regulate the motions of a watch. This escapement is a very good one. It is one of the simplest in construction; at the same time, it requires the most delicate adjustment and first-class workmanship. The impulse is given directly, so that it goes without oil; but it never allows the balance to be perfectly free from the train, as the long tooth is always rubbing against the axis. It requires less frequent cleaning than the lever, and, with careful wearers, gives equally good results. Where, however, it is subjected to a rotatory motion, such as many people give to their watches in the action of winding them, it is liable to set—that is, to stop—owing to the motion communicated to it. It also occasionally trips—that is, allows two teeth to pass the notch instead of one—when the motion is such as to accelerate the balance. This escapement, owing to its inferiority to the lever for general use, was gradually dying out. It has, however, been lately made in large numbers of very cheap watches by the Waterbury Watch Company, in America.

The horizontal, as it was called, to distinguish it from the old vertical escapement, and now usually known as the cylinder escapement, was invented by the celebrated English watchmaker, Graham, about the year 1720. It was never largely used in the country of its birth, but it was so extensively adopted by the French and Swiss that at one time nearly all their watches were made with this escapement. Its principles have been so thoroughly investigated by the latter nation that it is still a favourite among them, though it is gradually being supplanted by the lever. It has the advantage of being compact, and the parts may be so proportioned that a sort of rough compensation for change of temperature can be produced with the ordinary balance; but it has the disadvantages of not being substantial, the impulses are given obliquely, rendering the use of oil a necessity, and the balance is never detached from the influence of the train. It also wants cleaning rather frequently. Saunier says that a cylinder watch, if small, should commence going with the second turn of the key, ordinary size at the third turn, and large ones on the fourth turn.

The lever escapement, otherwise called the detached or patent lever, is generally known on the continent of Europe as the anchor escapement. It seems to have been first conceived in France. It was invented, however, in its present shape by Mudge, of London, about ninety years ago. The English, as became their practical character, took kindly to this escapement, and for many years it formed one of the principal features of an English watch. It is now, however, in great use everywhere, and seems likely to supersede all the other forms, for watches which have to be worn. It has the advantages of being simple and substantial, and, above all, it leaves the balance quite free from the influence of the train during nearly the whole of its vibration. The impulses are given obliquely, so that it requires oil, and therefore more frequent cleaning than direct impulse escapements. It has proved itself capable, however, of giving results nearly equal to those of the chronometer escapement —indeed, when the watch is worn in the ordinary way, I think it will prove the better timekeeper of the two.

The chronometer, detent, or detached escapement is the one universally employed in the large class of watches, usually called chronometers, used for finding the longitude at sea. It is occasionally employed in the superior sort of watches known as pocket chronometers—indeed, many watchmakers maintain that only watches with this escapement are entitled to be called chronometers. They therefore term the superior class of lever watches furnished with a chronometer balance half-chronometers. In this escapement the impulses are given directly, and the balance is completely free from the influence of the train. It works without oil, and though delicate in construction, it gives the best results as a timekeeper where the watch is kept in one position, as in marine chronometers. In pocket watches, however, it is, in my opinion, a mistake, and is not so trustworthy as the lever.

Although many other escapements have been proposed and constructed—indeed, scarcely any year passes without a new one being invented—yet the five just mentioned are now the only ones in common use. We will therefore pass on to the consideration of the hairspring and balance.

As mentioned before, Hooke was the first to study the action of springs. He found that the amount of bending of a spring was proportional to the weight that produced it, or, as he expressed it in the learned language of the time, "*ut tensio sic vis.*" From this property, then, when a spring is set vibrating, all the vibrations, whether long or short, ought to be isochronal—that is, performed in the same time. If Hooke had carried out his experiments more carefully, he would have found that in practice this did not strictly apply. The complete investigation was carried out by the celebrated French horologist, Pierre Le Roy, who, in the year 1766, announced his discovery in the following terms:—"There is in every spring, providing it be long enough, a length that causes all the vibrations, whether long or short, to be isochronal. Having fixed upon this length, if you shorten the spring the long vibrations will be quicker than the short. If, on the other hand, you lengthen it, the short arcs will occupy less time than the long." The great object in a good timekeeper, therefore, is to secure a good spring, determine its isochronal point, fix it there, and attach to it a balance of the proper weight and size, so that its inertia, combined with the elasticity of the spring, may cause them to vibrate in the interval of time required by the train, generally one-fifth of a second in a watch and one-fourth of a second in a marine chronometer. No alteration in the length of the spring should be made after this. Any change of rate that may be required should be brought about by changing the weight or dimensions of the balance. In marine and some pocket chronometers this procedure is strictly observed. In watches, however, change of rate is generally made by altering the length of the spring, as any interference with the balance of a watch that has to go in all positions would be likely to produce much larger errors than would result from a slight deviation from the isochronal length of the spring; and here it may be remarked that the usual way of making this alteration by means of a lever, containing two curb pins, which works radially round the spring, is by no means delicate enough. Some of the Waltham watches have very beautiful arrangements for this purpose, so that very minute alterations may be easily effected. Yet, strange to say, I find only their watches in hunting cases so provided; the similar grades of open face watches have the ordinary radial arm. The usual form of balance spring for watches is the well known flat spiral. In marine chronometers the heliacal spring is used, and for lever watches of the best class, especially those that have large arcs of vibration, amounting occasionally to 540 degs., a flat spring, with the outer end bent over and fixed not far from the centre coil, is preferred. Such a spring is known among the English as a Breguet, or overcoil, spring. The French call it *spiral coudé*. Many other forms of springs are sometimes found, but, judging from the results of the severe timing contests that take place among the Swiss manufacturers, no one form of spring is certain of proving itself superior to another. From what has been said above it will be seen that the selection of a proper spring for a watch demands great care, for unless the spring be isochronal great variations of rate would take place during the day, as the arc of vibration diminished with the uncoiling of the mainspring. This diminution, according to the observations of M. Phillippe, amounts to from 65 to 112 degrees. The English have endeavoured to evade this difficulty by the use of a fusee to equalise the force of the mainspring. This, however, considerably complicates the mechanism. It also renders rather difficult the application of the keyless mechanism, which is fast superseding the old style of winding, and worthily so, for, independently of its great convenience, the winding is done in a plane at right angles to that of the watch, so that there is no fear of disturbing the arc of vibration, as is done by those careless persons who, when they wind with a key, turn the watch as much, or even more, than the key itself. Keyless watches also keep clean longer than others. It has been remarked that the introduction of the keyless watch will be the death blow to the fusee. Strictly speaking every mainspring should have its own proper fusee, a point that was generally attended to in the best class of old verge watches; but

I suppose that it is owing to want of attention to this that I frequently find expensive English watches, furnished with a fusee, showing a greater variation of rate during the twenty-four hours than a Waltham watch without fusee and without stopwork. Very likely the Swiss going barrel watches would go as well, but I have not had the opportunity of testing high class Swiss watches. Those that were officially tested at the Observatory during the Exhibition trials were only timed once in twenty-four hours. In these circumstances this variation would not show itself. As a matter of fact, I have in my possession a Waltham watch purchased in Melbourne four years ago. It has such a long mainspring and runs so easily that it will go forty-eight hours without stopping. I have on three or four occasions forgotten to wind it, so that at the end of the two days I have found it moving very sluggishly, barely escaping, yet the greatest difference of rate I have found from this cause has been only nine seconds a day. It is sometimes less. The last occasion was on the 8th of the present month, when it was not wound. The two previous rates had been 5·7 secs. and 5·5 secs. losing, and between the 6th and the 8th the rate was 1·7 secs. losing.

Supposing the watch to be now put together in good condition and the balance perfectly poised, we will consider the causes that will make it change its rate. First and foremost will be change of temperature; and unfortunately its effects will be all in one direction, an increase of temperature will weaken the elasticity of the balance spring, increase its length, and also enlarge the diameter of the balance, each of which makes the watch go slower, so that the whole effect will be the sum of these partial ones. A decrease of temperature will act in a contrary direction, and cause the watch to gain. By far the principal cause of variation is the alteration of the elasticity of the spring; according to experiments made by Berthoud, and confirmed by Mr Dent, the effect of this amounts to more than four times that of the enlargement of the balance, and that the total effect will be to make an ordinary watch lose 63 seconds a day for an increase of 10° Fahr.; whereas an ordinary clock with an iron rod to the pendulum would only lose 3 seconds a day for the same increment of heat. To obviate this difficulty, the first chronometers were supplied with an apparatus that moved the curb pins, and thus shortened the effective part of the balance spring as the temperature increased; as this plan interfered with the isochronal quality of the spring, it was soon abandoned in favour of the compensation balance invented by Julien Le Roy, and afterwards much improved by Arnold and Earnshaw, who left it in very nearly the form it has retained ever since. According to this construction, the balance, instead of being a complete circle, consists of a steel cross bar, to each end of which is fixed a nearly semi-circular strip. These strips are composed of two metals, brass on the outside and steel on the inside. The old makers used to connect these metals by a number of very fine rivets. The modern practice is to melt one on the other. Screws called timing screws are fixed at the end of the cross-bar; any motion of these simply alters the inertia of the balance, without interfering with the compensation. They are therefore used for changing the rate. Heavy screws or weights are also attached to the bi-metallic strips. These are moved further from or nearer to the cross-bar, as we want to increase or diminish the effect of change of temperature. This balance acts in the following manner:—An increase of heat will cause the brass on the outside to expand more than the steel on the inside. This will cause the strips to curve inwards, and carrying the weights with them they thus diminish the inertia of the balance and compensate for the diminished elasticity of the spring; a decrease of heat will in a similar manner make them open outwards, and increase the inertia of the balance. This is still the style of balance most generally used. It is called simply a compensation balance. Its action, however, is not perfect. This was first explained by Mr. Dent, in 1833, though its defect had been a matter of observation in good chronometers for some time before. It was found that while the chronometer would go very well for a moderate range of temperature, yet it always lost above or below these limits when the range was considerable; or, if it went right at two extreme temperatures, it always gained at the mean one. The explanation is this: The effects of temperature on the spring would cause changes in its strength proportional to the changes of temperature. To compensate for this the moments of inertia of the balance ought to change in the same proportion. Instead of this, however, equal variations of heat will cause the compensating weights to alter their distances from the centre of the balance by equal variations of space; but the moments of inertia of the balance are proportional, not to the distances of the weights from the centre, but to the squares of these distances, so that while graphically the effect on the spring would be represented by a straight line, that on the balance would be a curve, which, near the point of contact with the straight line, would nearly coincide with it for a moderate distance, or would cut it in two points with a moderate deviation half-way between them. It is in the latter way that the chronometer is generally adjusted, so that it goes right at 55° and 85°, and it then gains about six-tenths of a second a day at 70°, the mean temperature. Various methods have been proposed for getting rid of this secondary error. The most successful seems to have been Kulberg's, which was exhibited in his marine chronometers at our late Exhibition. Another plan, invented by the superintendent of the Waltham factory, was used in some of their watches tested at the Observatory. The watches, however, were in very bad order, so that its efficiency was not made apparent. Watches that are carried in the pocket by day and placed under the pillow at night are in a great measure guarded from extreme changes of temperature. Carriage and similarly governed clocks are generally, however, exposed to great and sudden variations, so that, if not well compensated, their going must be greatly inferior to that of a common pendulum clock. From records kept at the Observatory I find that the maximum temperature of my room there, which has thick walls and a room above it, during the last ten years has been 90°, and the minimum 47°. This would cause a difference of four and a-half minutes a day in an uncompensated watch. In a weatherboard-lined room at my quarters, without a fire-place, the maximum has been 102°, and the minimum 31·5°. I have also carried a delicate thermometer in my watch pocket, to ascertain the temperature a watch is ordinarily submitted to. Sitting in my room where the thermometer indicated 59·3°, the temperature of the pocket was 82·4°. Another time the room was 58·0°; pocket, 80·0°. Open air, 55·5°; pocket, 70·4°. Air, 57·5°; pocket, with back to the sun, 72·0°; facing the sun, 81·0°. Bedroom, 63·0°; under pillow, 71·5°. Air 91·0°; pocket, 85·1. Room, 74·0°; pocket, 85·0°. Bedroom, 77·0°; under pillow, 81·8°. Air, 101·0°; pocket, in shade, 96·4°. Bedroom, 52·0°; under pillow, 59·0. Air, 50·0°; pocket, 71·0°. According to the above observations, the watch had been kept in temperatures varying from 59·0° under the pillow to 96·4° in the watch pocket while walking in the open air. This would correspond to a variation of nearly four minutes a day for a common watch, and shows how utterly useless all such refinements as finish, jewelled holes, &c., are to the timekeeping qualities of a watch if it is not provided with a compensation balance. One objection I have heard urged against the compensated balance is that, necessarily being heavy to get sufficient change of inertia, it is not suited for riding or other violent exercise. If this objection has a real foundation, it may be met by reverting to the old compensation curb, when the balance might be made as light as possible. It would also have the advantage of not being put out of poise by the alteration of the compensating weights. Decided objections might be raised to this in the case of the highest class watches, where the spring is firmly fixed to the collet and stud, and has no curb pins; but where a lever and curb pins are already fixed, as in most watches, I do not see why they should not be moved automatically as well as by hand.

A marine chronometer, properly adjusted for temperature as above, ought now to be in a condition to perform very well, as it is only kept in one position, except during the few seconds while it is being wound. A pocket watch, however, which is expected to go equally well in any position, needs very delicate adjustment in the poising of the balance and the regulation of the friction of the pivots. It will, I expect, surprise many persons when they know the high ratio the adjusting of a watch bears to its first cost. From an official return I find that the average price of the English watches sent to Australia is £5 8s. Of the foreign ones that come here *viâ* England the average price of the gold ones is £8 15s., and the silver ones 27s. Now, I am informed that in Geneva, where labour is not at all highly paid, an adjuster at the factories gets 25 francs, equal to £1 for each watch, and I see, from a discussion in the *English Mechanic*, that the principal London makers charge from 50s. to 60s. for adjusting a watch in temperature and position. To show the large errors even expensive watches are sometimes afflicted with, I append the following table, and I may state that I have only selected new watches for this purpose :—

Daily Rates of Watches in Six Different Positions.

Positions.	*a.*	*b.*	*c.*	*d.*	*e.*	*f.*	*g.*
	s.	s.	s.	s.	s.	s.	s.
Pendant up -	4·00	5·71	0·00	5·19	10·37	9·00	9·3
„ right	2·14	4·69	1·61	2·98	6·58	7·05	7·3
„ down	0·00	0·00	0·14	0·99	0·00	0·37	0·0
„ left -	2·27	4·12	2·99	4·60	2·58	0·00	11·6
Face up - -	3·89	1·21	2·29	0·99	7·32	9·38	0·0
„ down -	6·69	1·49	4·06	0·00	4·45	10·20	19·3

Positions.	*h.*	*i.*	*j.*	*k.*	*l.*	*m.*
	s.	s.	s.	s.	s.	s.
Pendant up -	40·1	2·2	83·0	0·0	0·0	253·1
„ right	13·0	0·0	165·0	117·2	86·5	0·0
„ down	0·0	58·5	4·0	175·5	254·7	372·3
„ left -	21·2	36·3	0·0	76·6	202·0	526·0
Face up - -	25·5	50·3	111·0	118·0	155·0	349·4
„ down -	31·3	58·9	119·0	91·0	156·9	350·0

The above numbers are not the actual rates, a constant having been added to each rate to make them all positive or gaining, and zero for the least rate.

a was the watch that came out best at the official testing; it had a pivoted detent escapement, called by the Swiss who made it, a bascule, and a heliacal spring. Melbourne retail price, about £50.

b was the best lever watch, it was English, Breguet spring. Price, in gold case, about £60.

c was the second best Swiss watch, lever escapement, Breguet spring.

d was the second best English lever, flat spring. Price, £64.

e was the best German watch, lever, Breguet spring, cost, £26 in gold case.

f was the second best German watch, lever, Breguet spring, cost, £10 18s. in silver case.

g was a cheap Waltham, purchased in Melbourne for £4 near the end of 1878.

h was a third grade Waltham, cost, £20 in gold case.

i was a fine finished London watch with a fusee, cost, £9 in silver case.

j was a fine finished London fusee watch, selected from the exhibition, cost, £9 10s. in silver case.

k was one of the cheapest Swiss cylinder watches, in nickel case, cost, retail, 25s.

l was one of the cheapest Swiss levers, in nickel case, cost, retail, 27s. 6d.

m was a machine made English lever, in silver case. Price, about 80s.

The Melbourne retail prices given above are estimated as nearly as possible from information supplied, the costs are given from actual sales.

RATES OF WATCHES CARRIED IN THE POCKET, A MARINE CHRONOMETER, AND AN ASTRONOMICAL CLOCK.

h.	*h.*	*h.*	*g.*	*g.*	*e.*	*e.*	*e.*	*i.*	*Marine Chronometer.*		*Astronomical Clock.*		
s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
+ 3·6	+ 2·4	+ 1·7	− 2·6	+ 0·5	− 3·3	− 1·6	− 3·0	+ 34·5	− 0·5	+ 0·4	− 0·39	− 0·24	+ 0·05
+ 4·0	+ 3·3	+ 4·7	− 2·6	− 1·6	− 3·3	− 2·2	− 2·3	+ 15·5	− 0·7	+ 0·3	− 0·37	− 0·16	+ 0·12
+ 2·2	+ 1·5	− 0·8	− 1·9	− 2·2	− 2·7	− 3·8	− 2·9	+ 33·5	− 0·2	− 0·2	− 0·47	− 0·22	+ 0·07
− 1·8	+ 1·0	− 0·5	− 4·3	− 1·2	− 2·2	− 3·8	− 3·3	+ 32·3	− 0·1	0·0	− 0·35	− 0·21	+ 0·05
+ 1·2	− 1·0	+ 5·0	− 3.8	− 2·6	− 1·1	− 3·7	..	+ 30·7	+ 0·5	− 0·3	− 0·42	− 0·36	+ 0·01
+ 0·9	+ 1·3	+ 1·2	− 4·5	+ 0·6	− 4·8	− 3·4	..	+ 24·5	+ 0·3	− 0·3	− 0·30	− 0·16	+ 0·06
+ 0·8	+ 2·3	+ 3·1	− 1·3	− 0·6	− 3·0	− 2·0	..	+ 30·4	+ 0·2	− 0·3	− 0·45	− 0·16	+ 0·15
− 0·3	+ 0·3	+ 0·5	− 3·3	− 1·8	− 1·2	− 3·5	..	+ 30·2	− 0·1	+ 0·1	− 0·24	− 0·19	+ 0·16
− 0·2	+ 0·7	+ 4·8	− 1·8	− 1·1	− 1·8	− 3·0	..	+ 24·1	− 1·3	− 0·2	− 0·31	− 0·19	+ 0·06
+ 2·3	− 0·7	+ 4·8	− 2·6	− 1·5	− 2·1	− 2·9	..	+ 35·4	− 0·8	0·0	− 0·40	− 0·30	+ 0·03
− 1·9	+ 2·2	+ 3·2	− 2·0	− 2·9	− 3·1	− 3·5	..	+ 30·1	− 0·3	− 0·3	− 0·39	− 0 27	− 0·06
− 1·7	+ 0·8	+ 2·3	− 2·4	− 0·1	− 2·8	− 3·7	..	+ 25·6	− 1·1	− 0·6	− 0·17	− 0·26	+ 0·02
− 0·9	− 1·6	+ 4·4	+ 0·7	+ 2·3	− 1·6	− 3·5	..	+ 30·1	− 0·5	+ 0·5	− 0·11	− 0·20	− 0·05
− 0·8	+ 3·4	+ 3·8	− 3·0	− 0·5	− 3·9	− 4·2	..	+ 33·2	− 0·3	− 0·6	− 0·18	− 0·22	+ 0·06
+ 1·8	+ 3·3	+ 4·2	− 0·5	− 1·6	− 1·8	− 2·7	..	+ 29·1	− 0·3	− 0·5	− 0·04	− 0·25	+ 0·10
+ 1·3	+ 2.4	+ 2·0	− 2·0	− 2·1	− 1·3	− 3·2	..	+ 30·9	+ 0·2	0·0	− 0·11	− 0·15	+ 0·09
− 1·3	+ 3·8	− 4·4	− 1·1	− 2·2	− 3·4	− 3·5	..	+ 34·2	0·0	− 0·4	− 0·19	− 0·02	+ 0·15
− 2·1	+ 2·8	+ 0·2	− 1·6	− 1·6	− 4·0	− 4·5	..	+ 34·0	− 0·4	− 0·1	− 0·11	+ 0·09	+ 0·16
− 5·9*	+ 0·3	+ 0·4	− 1·8	− 1·1	− 2·4	− 4·0	..	+ 25·5	0·0	0·0	− 0·19	+ 0·02	+ 0·26
− 0·9	+ 2·6	− 0·1	− 3·3	+ 0·6	− 2·9	− 3·3	..	+ 9·1	+ 0·3	+ 0·5	− 0·09	− 0·06	+ 0·19
− 0·7	+ 3·6	− 2·5	− 4·2	− 2·2	− 3·4	− 4·0	..	+ 38·7	+ 0·3	0·0	− 0·15	+ 0·08	+ 0·34
+ 0·1	+ 3·2	− 0·3	− 3·7	− 1·5	− 2·7	− 2·7	..	..	− 0·4	0·0	− 0·24	+ 0·04	+ 0·27
+ 3·0	− 1·6	+ 2·6	− 5·7	− 0·9	− 2·5	− 3·3	..	..	− 0·3	0·0	− 0·16	+ 0·08	+ 0·27
+ 0·2	+ 2·2	+ 0·1	− 5·3	− 0·4	− 4·9	− 3·4	..	..	− 0·1	0·0	− 0·25	+ 0·01	..
+ 1·2	+ 0·6	− 5·1	− 3·4	− 0·7	− 2·0	− 4·1	..	..	− 0·2	0·0	− 0·24	+ 0·01	..
+ 1·1	+ 1·5	− 1·0	− 1·8	− 2·1	+ 0·4	− 2·7	..	..	− 0·1	− 0·4	− 0·39	− 0·01	..
+ 1·1	+ 1·9	+ 0·2	− 2·8	− 0·2	− 3·5	− 4·8	..	..	− 0·2	− 0·7	− 0·21	+ 0·09	..
+ 1·2	+ 1·7	+ 2·0	− 1·2	− 1·4	− 1·3	− 3·0	..	..	− 0·1	− 0·4	− 0·25	+ 0·02	..

* Not wound for 38 hours.

In referring to the above list of watches, it may be mentioned, that *a, b, c, d, e,* and *f* were specially selected and adjusted by the makers for exhibition and competitive trial, the others were purchased from ordinary stock. The marine chronometer is a very fine one by George Timewell, of Liverpool, which has not been cleaned for four years, and the astronomical clock is the celebrated Frodsham 991, which, when its rates were examined by the horological jury of the Paris exhibition of 1867, was pronounced to be one of the best in existence, its rates are found by celestial observations, generally taken every second or third day. Those given in the above list extend from near the beginning of February to the end of August in the present year, they, therefore, include the hottest and coldest periods, the gradual change of rate is owing to the clock being slightly under-compensated. The iron jar containing the quicksilver is only 8½ inches long inside; this has proved to be not quite enough. The rates of the watches and chronometer have been determined by means of daily comparisons with the standard mean time clock of the observatory, they have all been obtained from trials made during the last few months, with the exception of watch *g*, whose rates are given for November and December 1879, as I have not often worn it since. All the errors of position have been determined since the beginning of last year. It should be stated also that the rates of the astronomical clock have been corrected for the variations of atmospheric pressure, as it has been found for this particular clock, that a rise of one inch of the barometer causes it to lose half a second per diem.

On examining the above table of rates, it will be seen at once to what enormous dimensions the error of position sometimes attains; in watch *m*, the English machine-made watch, it amounts to a daily difference of eight minutes and forty-six seconds between pendant right and pendant left; while in the Waltham, costing the same money, and also a machine-made watch, the greatest difference is only nineteen seconds. Again, in watch *j*, a finely-finished London fusee watch, the error reaches two minutes forty-five seconds a day. Comparing these with the two high-class expensive London watches *b* and *d*, whose largest errors of position are only somewhat over five seconds, it shows what English watchmakers can do when they are well paid for their work; their ordinary watches, however, are very badly adjusted, and if they do not improve in this particular, they are likely to lose their trade. According to a notice in the *Horological Journal,* Australia is England's best customer for watches, still the manufacture has lately fallen off to such an extent, that England does not now export one watch per head of her watchmaking population. The competition the English have to contend against is shown in the case of watch *g,* whose rates were given before, which came into my possession in a very ordinary way. On passing down Swanston-street I saw it in Mr. Joseph's window; it was simply marked "Waltham," with the price, four guineas, attached. I went in on the afternoon of December 4th, 1878, purchased it, and took it home with me. I compared it with our standard clock, and got the following results :—

Date.				Error.	Date.				Error.
	d.	h.	m.	s.		d.	h.	m.	s.
Dec.	4.	5	26	12 slow	Dec.	8.	21	0	13·5 slow
„	4.	21	0	13 „	„	9.	1	0	12·5 „
„	5.	21	0	12·0 „	„	9.	5	5	11·2 „
„	6.	1	0	13·0 „	„	9.	21	3	11·3 „
„	6.	4	0	12·5 „	„	10.	1	0	10·5 „
„	6.	21	0	12·5 „	„	10.	4	0	10·5 „
„	7.	7	23	12·0 „	„	10.	9	35	10·5 „
„	7.	20	31	12·5 „	„	10.	22	12	12·0 „

I was fairly astonished at such a result. On the last mentioned day I left Melbourne for New Zealand. During the voyage I used the watch as a chronometer for finding the longitude, as I had carried a small sextant with me for my amusement. On reaching Dunedin I found that in seven days the watch had altered its error about half a minute, having lost more in the much colder temperature at sea, than in Melbourne. I subsequently found by direct experiment that it was over-compensated to the extent of gaining twelve seconds a day for an increase of ten degrees Fahr. About a year ago I had the screws shifted, and the compensation is now nearly perfect. I still occasionally wear it, and it goes as well as ever; the improvement in the compensation being partly neutralised by an increase in the position error. Mr. Dent says that an adjusted going barrel lever may be expected, with an ordinary wearer, to have a daily variation of rate from 2 to 4 seconds. The above watch did not profess to be adjusted, yet it is within those limits; I consider myself, however, a careful wearer.

To dispense with the tedious and expensive process of adjustment for position, an arrangement has been introduced by the Swiss, called a "tourbillon." In this system the escapement and balance are mounted on a frame which makes a complete turn in the watch every two or three minutes. Some of these tourbillons have given very good results. The method does not seem, however, to be growing into favour, owing, perhaps, to its being less stable than the ordinary construction. A somewhat similar plan is found in the Waterbury watches, mentioned before in connection with the duplex escapement, where the whole movement turns in the case once in an hour.

As a final remark to the purchasers and owners of watches, I would say to the former, buy your watches from trustworthy men—those whose words are as good as their bonds. Do not be led away by surface appearances, the number of jewels, &c. Saunier remarks that—"In a vast number of modern watches, and, unfortunately, even in many of those which pretend to be of superior quality, the jewels are rather a blind than in any sense beneficial. Badly worked and of insufficient hardness, these are less serviceable than good, carefully hammered brass." Watch jewels are by no means so valuable as is usually supposed. The cost of a jewelled hole of good average quality, ready for fixing in the plate, is, I am informed, in Geneva, only one shilling. The Swiss occasionally put a glass back to their watches in place of the usual metal dome, so that the works may be seen without opening and exposing them to dust, &c. It is a very bad style, however, for should the glass get fractured the particles fall at once into the movement, and do great damage. I am told that one of the fine Swiss watches that came out highest at our Observatory testing has been lately irretrievably ruined owing to this. Compensation balances also, unless carefully made, are worse than plain ones, for, independently of their never having been adjusted, the arms oftentimes move unequally with change of temperature, and thereby cause great errors of position. As a general remark, it may be stated that good watches are seldom unsightly. To the owners of good watches I would say, treat them with the greatest care and gentleness, for they are most delicate machines, and worthy of being treasured as specimens of man's intelligence and manipulative skill. Never allow them to go so long as to stop of themselves from the drying of the oil and the accumulation of dirt, for excessive wear results from this. As a general rule two years is the longest time a good watch should go without cleaning, especially if it is wound with a key, which conveys most of the dirt into the interior, as may easily be seen by an inspection of the winding square. Dust proof cases and keyless winding may enable a watch to perform well for a longer period than two years, but it will be found bad economy in the end to allow them to do so. Above all, never trust good watches with inferior workmen. A good watch is easily ruined, but restored with great difficulty. In the present state of the watch manufacture, where the division of labour is so minutely carried out, the watch repairer, or jobber, as he is sometimes contemptuously called, requires more science and skill in his work than the watchmaker. In conclusion, I would recommend to those engaged in practical watchwork the large treatise by Saunier, an English edition of which has been lately issued ; and to those who only take an interest in the matter, the little book in Weale's series by Sir Edmund Beckett, Bart., on clocks and watches, where diagrams will be found of the different escapements, &c., mentioned in this paper, and where the subject is treated in such a charming and popular manner that, although the work is full of information, it is as entertaining as a novel.
